

WHAT IS CLAIMED IS:

- 1 1. A method of forming a planar waveguide structure, comprising:
2 forming a first graded layer on a substrate, the first graded layer comprising silicon
3 and germanium wherein the germanium concentration increases with the height of the first
4 graded layer; and
5 forming a second graded layer on the first graded layer, the second graded layer
6 comprising silicon and germanium wherein the germanium concentration decreases with the
7 height of the second graded layer.
- 1 2. The method of claim 1 further comprising forming a blocking layer between the
2 substrate and the first graded layer wherein the blocking layer prevents contaminants from the
3 substrate from diffusing into the first or the second graded layers.
- 1 3. The method of claim 2 wherein the blocking layer comprises epitaxial silicon.
- 1 4. The method of claim 1 further comprising forming a cladding layer on the second
2 graded layer.
- 1 5. The method of claim 4 wherein the cladding layer comprises epitaxial silicon.
- 1 6. The method of claim 1 wherein the germanium concentration in the first graded layer
2 increases linearly.
- 1 7. The method of claim 1 wherein the germanium concentration in the graded layer
2 increases from about 0% germanium to about 2-5% germanium at a rate between about 0.1%
3 per μm to about 10% per μm .
- 1 8. The method of claim 1 wherein the germanium concentration in the first graded layer
2 increases from about 0% germanium to about 2% germanium at a rate of about 10 % per μm .
3

- 1 9. The method of claim 1 wherein the germanium concentration in the second graded
2 layer decreases linearly.
- 1 10. The method of claim 1 wherein the germanium concentration in the second graded
2 layer decreases from about 2-5% germanium to about 0% germanium at a rate between about
3 0.1% per μm to about 10% per μm .
- 1 11. The method of claim 1 wherein the germanium concentration in the second graded
2 layer decreases from about 2% germanium to about 0% germanium at a rate of about 10% per
3 μm .
- 1 12. The method of claim 1 wherein the layers are formed by a chemical vapor deposition
2 process.
- 1 13. The method of claim 12 wherein the layers are formed epitaxially.
- 1 14. The method of claim 12 wherein the chemical vapor deposition process is a low
2 pressure chemical vapor deposition process.
- 1 15. The method of claim 13 wherein the waveguide structure is formed using a selective
2 deposition technique.
- 1 16. The method of claim 13 wherein the chemical vapor deposition process comprises
2 introducing into a deposition chamber a first source gas for forming silicon film on a
3 substrate;
4 introducing into a deposition chamber a second source gas for forming SiGe film on a
5 substrate;
6 introducing H_2 into the deposition chamber
7 while maintaining a determined pressure and temperature in the deposition chamber.
- 1 17. The method of claim 16 wherein the first source gas is silane, disilane, trisilane,
2 dichlorosilane, or trichlorosilane.

1 18. The method of claim 16 wherein the second source gas is germane or digermane.

1 19. The method of claim 16 wherein the first source gas is silane and the second source
2 gas is germane.

1 20. The method of claim 16 wherein the chemical vapor deposition process for forming
2 the first and second graded layers comprises
3 controlling the flow rate of the second source gas according to a determined
4 concentration profile of Ge on a substrate;
5 forming a film on a substrate, the film comprising Ge at a first concentration at a first
6 point in the film and a second concentration different from the first concentration at a second
7 point in the film.

1 21. The method of claim 20 wherein the concentration profile is determined by:
2 determining a concentration of Ge formed on a substrate for a plurality of flow rates;
3 determining a growth rate of SiGe on a substrate for a second plurality of flow rates;
4 determining a concentration profile of Ge for a unit of time; and
5 controlling the flow rate to form film at a graded concentration of Ge throughout the
6 thickness of the film.

1 22. The method of claim 1 further comprising:
2 forming a pattern on the first graded layer; and
3 etching the patterned first graded layer before forming the second graded layer on the
4 first graded layer.

1 23. A method of forming a planar waveguide structure, comprising:
2 forming a first graded layer on a substrate, the first graded layer comprising silicon
3 and germanium wherein the germanium concentration increases with the height of the layer;
4 forming a uniform layer on the first graded layer, the uniform layer containing silicon
5 and germanium wherein the germanium concentration is constant;
6 forming a second graded layer on the uniform layer, the second graded layer
7 comprising silicon and germanium wherein the germanium concentration decreases with the
8 height of the second graded layer.

1 24. The method of claim 23 wherein the germanium concentration in the uniform layer is
2 in the range of about 2 - 5 %.

1 25. The method of claim 23 wherein the germanium concentration in the uniform layer is
2 approximately 2%.

1 26. The method of claim 23 wherein the thickness of the uniform layer is in the range of
2 about 2-5 μm .

1 27. The method of claim 23 wherein the thickness of the uniform layer is approximately 2
2 μm .

1 28. The method of claim 23 further comprising forming a blocking layer between the
2 substrate and the first graded layer.

1 29. The method of claim 29 wherein the blocking layer is epitaxial silicon.

1 30. The method of claim 23 further comprising forming a cladding layer on the second
2 graded layer.

3 31. The method of claim 30 wherein the cladding layer is epitaxial silicon.

1 32. The method of claim 23 wherein the germanium concentration in the first graded layer
2 increases linearly.

1 33. The method of claim 23 wherein the germanium concentration in the first graded layer
2 increases from about 0% germanium to about 2-5% germanium at a rate between about 0.1 %
3 per μm to about 10% per μm .

1 34. The method of claim 23 wherein the germanium concentration in the first graded layer
2 increases from about 0% germanium to about 2% germanium at a rate of 10 % per μm .

1 35. The method of claim 23 wherein the germanium concentration in the second graded
2 layer decreases linearly.

1 36. The method of claim 23 wherein the germanium concentration in the second graded
2 layer decreases from about 2-5% germanium to about 0% germanium at a rate between about
3 0.1 % per μm to about 10% per μm .

1 37. The method of claim 23 wherein the germanium concentration in the second graded
2 layer decreases from about 2% germanium to about 0% germanium at a rate of about 10 % per
3 μm .

1 38. The method of claim 23 wherein the layers are formed using a chemical vapor
2 deposition process.

1 39. The method of claim 38 wherein the layers are formed epitaxially.

1 40. The method of claim 38 wherein the chemical vapor deposition process is a low
2 pressure chemical vapor deposition process.

1 41. The method of claim 38 wherein the waveguide structure is formed using a selective
2 deposition technique.

1 42. The method of claim 29 wherein the chemical vapor deposition process comprises
2 introducing into a deposition chamber a first source gas for forming silicon film on a
3 substrate;
4 introducing into a deposition chamber a second source gas for forming SiGe film on a
5 substrate;
6 introducing H₂ into the deposition chamber
7 while maintaining a determined pressure and temperature in the deposition chamber.

1 43. The method of claim 42 wherein the first source gas is silane, disilane, trisilane,
2 dichlorosilane, or trichlorosilane.

1 44. The method of claim 42 wherein the second source gas is germane or digermane.

1 45. The method of claim 42 wherein the first source gas is silane and the second source
2 gas is germane.

1 46. The method of claim 42 wherein the chemical vapor deposition process for forming
2 the first and second graded layers comprises
3 controlling the flow rate of the second source gas according to a determined
4 concentration profile of Ge on a substrate;
5 forming a film on a substrate, the film comprising Ge at a first concentration at a first
6 point in the film and a second concentration different from the first concentration at a second
7 point in the film.

1 47. The method of claim 46 wherein determining the concentration profile comprises:
2 determining a concentration of Ge formed on a substrate for a plurality of flow rates;
3 determining a growth rate of SiGe on a substrate for a second plurality of flow rates;
4 determining a concentration profile of Ge for a unit of time; and
5 controlling the flow rate to form film at a graded concentration of Ge throughout the
6 thickness of the film.

1 48. The method of claim 23 further comprising:
2 forming a pattern on the uniform layer; and
3 etching the patterned uniform layer and the first graded layer before forming the
4 second graded layer on the uniform layer.

1 49. The method of claim 48 further comprising:
2 forming an oxide layer on the etched patterned uniform layer before forming the
3 second graded layer on the uniform layer.

1 50. The method of claim 49 wherein the height of the oxide layer is approximately equal to
2 the height of the first graded layer.

1 51. A computer readable medium comprising executable program instructions that when
2 executed cause a digital processing system to perform a method comprising:
3 forming a first graded layer on a substrate, the first graded layer comprising silicon
4 and germanium wherein the germanium concentration increases with the height of the first
5 graded layer;
6 forming a second graded layer on the first graded layer, the second graded layer
7 comprising silicon and germanium wherein the germanium concentration decreases with the
8 height of the second graded layer.

1 52. The method of claim 51 wherein the executable program instructions include
2 instructions for forming layers using chemical vapor deposition process.

1 53. The method of claim 51 wherein the chemical vapor deposition process comprises
2 executable program instructions for:
3 introducing into a deposition chamber a first source gas for forming silicon film on a
4 substrate;
5 introducing into a deposition chamber a second source gas for forming SiGe film on a
6 substrate;
7 introducing H_2 into the deposition chamber
8 while maintaining a determined pressure and temperature in the deposition chamber.

1 54. The method of claim 51 wherein the executable program instructions for forming the
2 first and second graded layers comprises instructions for:

3 controlling the flow rate of the second source gas according to a determined
4 concentration profile of Ge on a substrate;

5 forming a film on a substrate, the film comprising Ge at a first concentration at a first
6 point in the film and a second concentration different from the first concentration at a second
7 point in the film.

1 55. The method of claim 54 wherein the executable program instructions for determining
2 the concentration profile comprises instructions for:

3 determining a concentration of Ge formed on a substrate for a plurality of flow rates;

4 determining a growth rate of SiGe on a substrate for a second plurality of flow rates;

5 determining a concentration profile of Ge for a unit of time; and

6 controlling the flow rate to form film at a graded concentration of Ge throughout the
7 thickness of the film.

1 56. The method of claim 51 wherein the executable program instruction include instructions
2 for forming the layers epitaxially.

1 57. A method of forming a planar waveguide structure, comprising:

2 etching a pattern in a substrate;

3 forming a first graded layer on the pattern etched in the substrate, the first graded layer
4 comprising silicon and germanium wherein the germanium concentration increases with the
5 height of the layer;

6 forming a uniform layer on the first graded layer, the uniform layer containing silicon
7 and germanium wherein the germanium concentration is constant;

8 forming a second graded layer on the uniform layer, the second graded layer
9 comprising silicon and germanium wherein the germanium concentration decreases with the
10 height of the second graded layer.

1 58. The method of claim 57 further comprising planarizing the uniform layer prior to
2 forming the second graded layer.

1 59. The method of claim 58 wherein the planarizing step is performed using a chemical
2 mechanical polishing process.

1 60. A method of forming a planar waveguide structure, comprising:
2 forming a first graded layer on a substrate, wherein the first graded layer comprises a
3 first and a second optical material, wherein the concentration of the first optical material and
4 the index of refraction of the first graded layer increases with the height of the first graded
5 layer;
6 forming a second graded layer on the first graded layer, the second graded layer
7 comprising the first and second optical materials wherein the concentration of the first optical
8 material and the index of refraction of the second layer decreases with the height of the
9 second graded layer.

1 61. A method of forming a planar waveguide structure, comprising:
2 forming a first graded layer on a substrate, wherein the first graded layer comprises a
3 first and a second optical material, wherein the concentration of the first optical material and
4 the index of refraction of the first graded layer increases with the height of the first graded
5 layer;
6 forming a uniform layer on the first graded layer, the uniform layer containing first and
7 second optical materials wherein the first optical material concentration is constant;
8 forming a second graded layer on the first graded layer, the second graded layer
9 comprising the first and second optical materials wherein the concentration of the first optical
10 material decreases with the height of the second graded layer;
11 wherein the index of refraction of the uniform layer is greater than the index of refraction of
the first and the second graded layers.

1 62. A method of forming a planar waveguide structure, comprising:
2 forming a uniform layer on a substrate, the uniform layer containing primarily
3 epitaxial silicon germanium wherein the germanium concentration is constant.

1 63. The method of claim 62 further comprising:
2 forming a cladding layer on the uniform layer, the cladding layer containing primarily
3 epitaxial silicon.

1 64. The method of claim 62 further comprising:
2 forming a pattern on the uniform layer; and
3 etching the patterned uniform layer.

1 65. The method of claim 64 further comprising:
2 forming a cladding layer on the patterned etched uniform layer, the cladding layer
3 containing primarily epitaxial silicon.

1 66. The method of claim 62 further including forming a graded layer on the uniform layer,
2 wherein the concentration of germanium decreases with the height of the graded layer, the
3 graded layer comprising primarily of epitaxial silicon germanium.

1 67. The method of claim 66 further including forming a cladding over the graded layer,
2 the cladding layer comprising primarily epitaxial silicon.